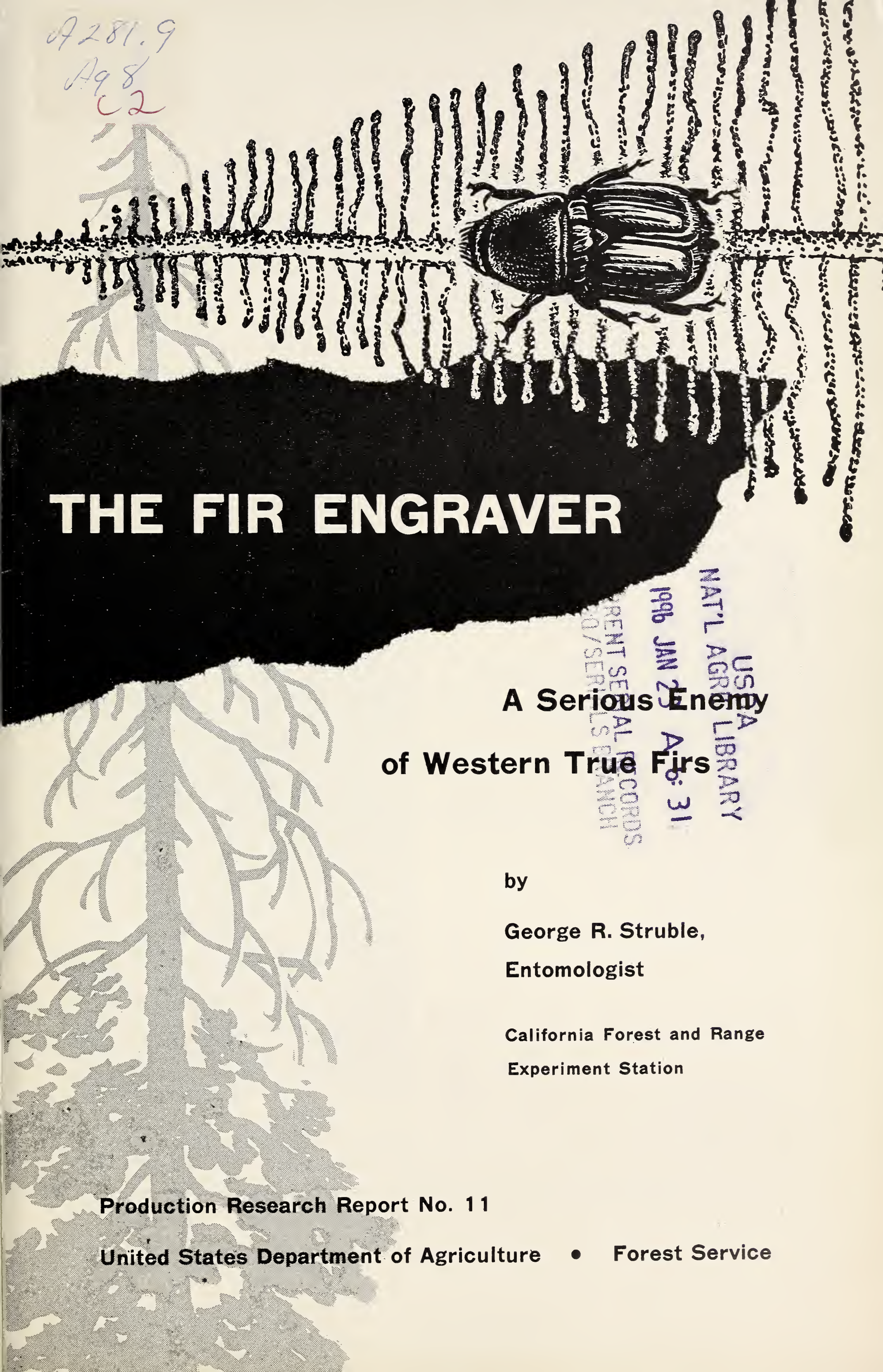

THE FIR ENGRAVER

A Serious Enemy of Western True Firs

by

George R. Struble,
Entomologist

California Forest and Range
Experiment Station

Production Research Report No. 11

United States Department of Agriculture • Forest Service

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THE FIR ENGRAVER

A Serious Enemy of Western True Firs

By George R. Struble,
Entomologist, California Forest and Range Experiment Station,[1] *Forest Service*

INTRODUCTION

The fir engraver (*Scolytus ventralis* Lec.) is a major enemy of true firs (*Abies* Mill.) in western forests. This bark beetle attacks trees from pole size to mature saw-timber. Some trees are killed during a single season (fig. 1); others are top killed, and often there is severe branch killing. Many trees, weakened through successive attacks, die slowly over a period of years. Even though they survive the injury, partially attacked trees may develop defects and rots which render them unfit for manufacture into lumber and other wood products.

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Figure 1.—Group of fading young white fir trees, the result of fir engraver attacks on the main stems.

Outbreaks of the fir engraver characteristically occur at irregular intervals and cause severe forest damage simultaneously in many widely separated localities. Such sporadic outbreaks have been recorded in California and Oregon at least once a decade since 1925. They have resulted in an estimated average annual loss in California alone of 450 million board-feet—the equivalent of more than half the estimated annual net growth of firs. Since 1935, outbreaks reported from Nevada, Utah, Arizona, and New Mexico have resulted in severe depletion of white fir in certain stands.

Like most other species of bark beetles, the fir engraver injures its host by attacking and mining along the cambium layer of the main trunk. The broods which develop then destroy large areas of the most vital part of the tree. Attacks are usually confined to the part of the

[1] Maintained at Berkeley, Calif., in cooperation with the University of California.

trunk larger than 4 inches in diameter. The upper half to third of the trunk is attacked most often, but at times infestations extend almost to ground level. Although many other species of bark beetles cannot develop broods without first killing the tree, the fir engraver is able to attack and establish broods when only part of the cambium area of the trunk has been killed.

Aside from its taxonomic position and description in the literature,[2] detailed knowledge of this important forest insect was lacking before 1928. In that year field studies were started in the central Sierra Nevada in California. This publication brings together information accumulated since then on the biology, habits, and control of the fir engraver. It also summarizes information on several other forest insects associated with the fir engraver.

HOSTS AND DISTRIBUTION

Fir engravers attack nearly all species of fir, but three species are most susceptible: white fir (*Abies concolor* (Gord. & Glend.) Lindl.), lowland white fir (*A. grandis* (Dougl.) Lindl.), and California red fir (*A. magnifica* A. Murr.). The fir engraver has also been collected from alpine fir (*A. lasiocarpa* (Hook.) Nutt.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Engelmann spruce (*Picea engelmanii* Parry), and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.). It has been found in British Columbia, Washington, Montana, Idaho, Utah, Oregon, California, Arizona, New Mexico, and Nevada.

LIFE HISTORY AND HABITS OF THE BEETLE

Adults

The mature adult is black, shining, from 3 to 5 mm. long, and more active than most bark beetles. In lateral profile the ventral part of the abdomen is incurved (fig. 2). Newly formed adults remain quiet for a period of 7 to 14 days or longer before boring to the outside of the bark, during which coloration deepens from light ivory to black. They may be observed from June 1 to September 10, but are most numerous in flight during July and August. Emergence is extended over such a long period that few beetles are seen in flight at any particular time. They have never been observed to fly in pairs, groups, or swarms, but often gather in numbers on cut logs.

Some feeding is done on the thin bark of the trunk and larger branches of fir trees during the period of flight, but not on the twigs and needles. Feeding at this time is probably directed toward finding a suitable spot for an attack.

Apparently, host trees are attacked at random. This is indicated by injured areas, scars, and healing tissue found on a large percentage of green fir trees in the forest. Repeated attacks, often extending over a period of years, weaken some trees beyond recovery. Other trees may be killed either entirely or at the top during one season.

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[2] BLACKMAN, M. W. A REVISIONAL STUDY OF THE GENUS SCOLYTUS GEOFFROY (ECCOPTOGASTER HERBST) IN NORTH AMERICA. U. S. Dept. Agr. Tech. Bul. 431, 31 pp. 1934.

LECONTE, J. L. APPENDIX. *In* ZIMMERMAN, C. SYNOPSIS OF THE SCOLYTIDAE OF AMERICA NORTH OF MEXICO. Amer. Ent. Soc. Trans. 2:50–78. 1869. (*See p.* 167.)

SWAINE, J. M. CANADIAN BARK-BEETLES. PART II. A PRELIMINARY CLASSIFICATION, WITH AN ACCOUNT OF THE HABITS AND MEANS OF CONTROL. Canada Dept. Agr. Ent. Branch Bul. 14, pt. 2, 143 pp., illus. 1918.

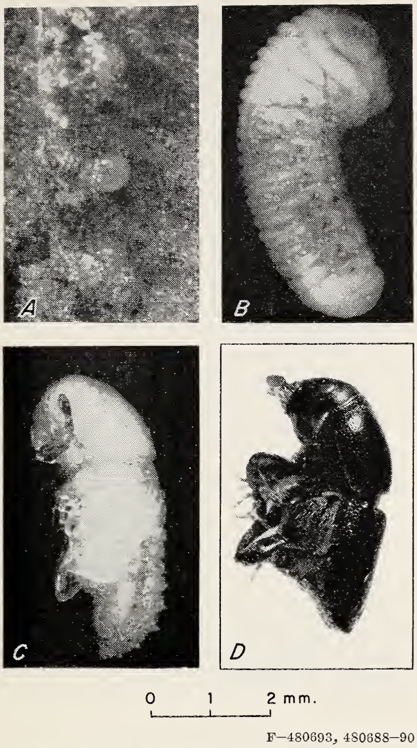

Figure 2.—Life stages of the fir engraver: *A*, Eggs; *B*, larva; *C*, pupa; *D*, adult.

The fir engraver readily attacks windfall firs. It also often attacks green cull logs resulting from logging operations, especially those that are sheltered from direct sunlight. In this habit of attacking blowdowns and logs, this insect is similar to many other bark beetles.

Attacks and Mating Habits

Attacks are made along the main trunk, usually in roughened bark surrounding the bases of branches. When the female beetle selects a suitable spot for attack, she rotates about the spot and cuts away bits of bark. Within 36 to 48 hours the newly excavated entrance hole slants upward to the cambium layer. The surfaces of the sapwood and inner bark are then deeply grooved to form a nuptial chamber large enough to accommodate two beetles.

Successful beetle attack is evidenced by the entrance holes and by reddish-brown boring dust in bark crevices and in cobwebs along the trunk and at the junction of branches with the trunk. Pitch tubes, characteristic of most attacks by bark beetles in pine, are never found in fir. Fir engraver attacks, however, are often indicated by scattered streamers of balsam on the upper bole.

The male beetle assists in removing debris soon after the female has bored into the bark a short distance. Before that time the male may have mated with several females, but eventually he selects a single mate and remains with her, mating many times during the egg-laying period. From 2 to 3 weeks before egg-laying is completed, the male abandons the female entirely. His later habits are unknown.

Construction of Egg Galleries

Excavation of egg galleries by the female is begun as soon as the nuptial chamber has been completed. Two horizontal galleries, cutting deeply both the sapwood and inner bark surfaces, are extended in opposite directions from the upper part of the nuptial chamber (fig. 3). When completed, each gallery is from 2 to 6 inches long, with the nuptial chamber at or near the center. Both galleries are started within the first week of egg laying, and construction of each continues alternately during a period of 5 to 7 weeks.

As soon as each gallery is extended beyond one-eighth inch from the nuptial chamber, tiny niches, spaced 1 to 1.5 mm. apart, are excavated along the cambium

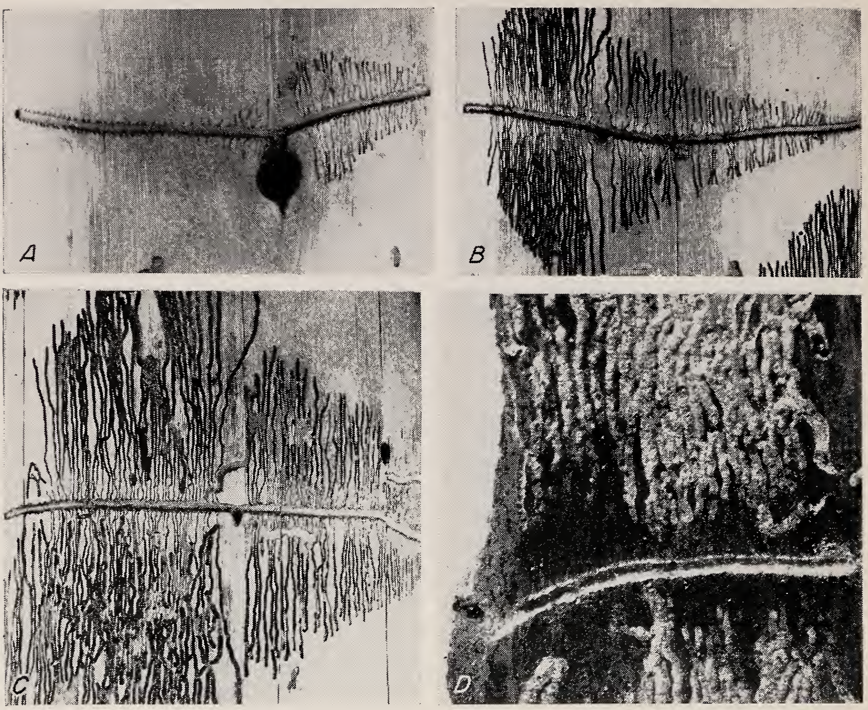

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Figure 3.—Character of galleries made by fir engraver, about two-thirds actual size: *A, B,* C, Egg galleries showing egg niches and varying lengths of larval channels etched on sapwood surfaces. Depression in center of gallery (C) known as nuptial chamber. *D,* Frass-filled larval mines of maturing brood along inner bark, and dead female adult plugging entrance to egg gallery.

layer on each side (fig. 3, *A*). One egg is deposited in each niche. The latter is then packed tightly with frass (fig. 2, *A*). From 100 to 300 eggs are deposited in the average completed gallery. The female then backs into the entrance hole and soon dies (fig. 3, *D*). This blocks the opening and apparently serves in some degree to prevent the entrance of predacious and parasitic enemies.

Development of Cambium Stain

Four to six days after an egg gallery is begun, a yellowish-brown discoloration of the cambium layer extends vertically from each side of the gallery (fig. 4). The discoloration spreads both upward and downward, indicating the dying of cambium areas. The stain is well established by the time the first eggs have hatched and continues to spread in advance of the feeding larvae. The cause is a fungus (*Trichosporium symbioticum*) described in 1935 by Wright.[3] Although the fungus is introduced by adult beetles and is constantly associated with newly established attacks, its relation to fir engraver broods has not yet been determined.

[3] Wright, E. trichosporium symbioticum, n. sp., a wood-staining fungus associated with scolytus ventralis. Jour. Agr. Res. 50: 525–538, illus. 1935.

However, inasmuch as the fungus tends to dry out the cambium layer, it may be an important factor in the successful establishment of broods.

In later stages of its development, the fungus stains the cambium layer deep reddish brown. In trees which have resisted attacks and in which old scars have healed, the evidence of attack is clearly indicated by the stained annual ring marking the year of attack.

Eggs

The tiny, ovid-cylindrical, pearly white eggs are deposited in niches excavated by female adults. From 9 to 14 days of incubation are required for eggs to hatch. By the time the last egg in a gallery is deposited (5 to 7 weeks after the first one), larvae varying in age up to 5 weeks old may be found.

Larvae

Each larva feeds separately in an individual mine that extends at right angles to the egg gallery. The inner bark and sapwood surfaces are both grooved, and frass is packed tightly in the mine. Six molts occur during the larval stage. When mature, each larva constructs a pupal chamber at the end of the feeding mine, in which it remains quiescent.

The time required for larvae to complete development depends on temperatures, which stimulate feeding or cause dormancy. The maximum period found was 380 days at 7,500 feet elevation; the minimum period was 41 days at 3,500 feet. All larvae remain dormant during the winter but resume feeding when rising temperatures occur in spring and summer.

Pupae

Pupae are found as early as May 14 in certain areas and not until July 1 in others, depending on elevation and the advancement of the season. They are rarely found after September 15. They develop rapidly, and within 10 to 14 days

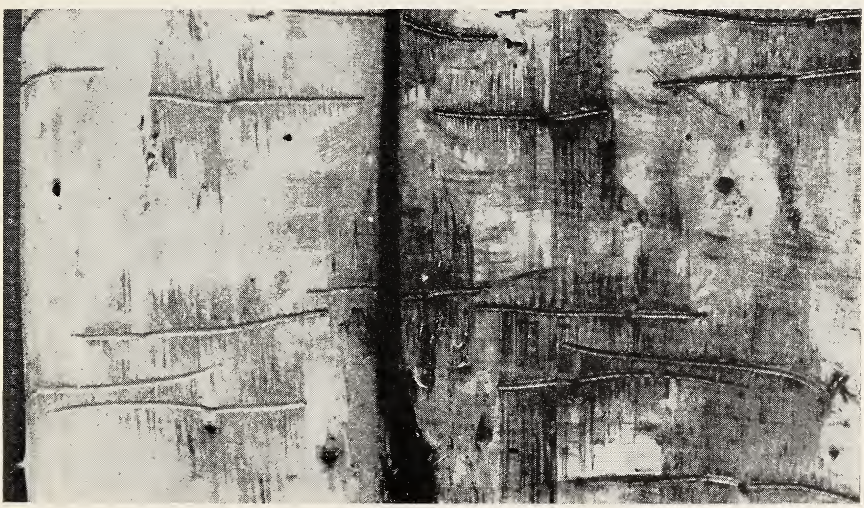

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Figure 4.—Section of white fir log with bark peeled back to show egg galleries of the fir engraver cutting the sapwood and inner bark surfaces, and the development of fungus stain. The stain is deeper on the inner bark than on the sapwood.

they change into adults. Pupae may be uncovered at any point from immediately beneath the sapwood surface to the outer bark; they are most common in the inner bark.

Seasonal Generations

The average rate of development throughout the Sierra Nevada fir belt (elevation 3,000 to 9,000 feet) is one generation a year at elevations between 4,500 and 6,000 feet. The minimum rate of development is at elevations above 6,000 feet on north exposures and above 8,000 feet on all exposures, where one generation is completed every 2 years. The maximum rate of development results in one complete and one partial generation a year at elevations between 3,500 and 4,500 feet on south exposures, depending on the duration of the warm summer season (fig. 5).

The influence of latitude on seasonal development is not well known, but it is expected that lower temperatures in the northern limits of the insect's range have a retarding effect. Although development has not been recorded elsewhere than in the areas studied in California, observational evidence by forest entomologists indicates a close similarity in other States.

Long periods of attack and egg laying apparently lengthen the developmental span of part of the brood, and it may extend over a second winter. New attacks on green logs have been found to continue 4 to 6 weeks, but most commonly persist for about 3 weeks. Since egg laying continues 5 to 7 weeks, the combination of attack and egg laying results in considerable overlapping of broods and causes some confusion about the age of the brood and the duration of the life cycle.

CHARACTER OF DAMAGE

Fading

Successful fir engraver attacks are manifested by fading foliage of branches that join the main bole near the point of attack (fig. 6). Attacks started in July and early in August cause the foliage to turn yellowish green within 4 to 6 weeks, and from sorrel to reddish brown some time later. Attacks started later in the summer seldom result in foliage changes until winter or early in the spring of the following year. Conspicuous fading branches scattered among green ones indicate that the cambium layer around the bases of fading branches has been girdled. Girdling of the cambium layer surrounding the trunk causes the top to fade above the girdled area. When the main trunk is girdled at or below the basal part of the crown, the entire crown fades at one time.

Embedded Scars

Injured areas along the main trunk (fig. 7, *A*) heal over if the trunk has not been completely girdled, and within a few years evidence of the attack is buried in the wood by the overgrowth of wood tissue following the year of attack (fig. 7, *B*, *C*). Deeply embedded scars have been dated as far back as 1865. External evidences of old attacks are often found as swellings or abnormal irregularities of the outer bark.

A tree near Pinecrest, Calif., revealed 7 different attacks from 1888 to 1929 (fig. 8). The last attack killed the tree. Egg galleries and fungus stain were preserved perfectly on each scar. In cross section, deeply stained annual rings marked the years of attack.

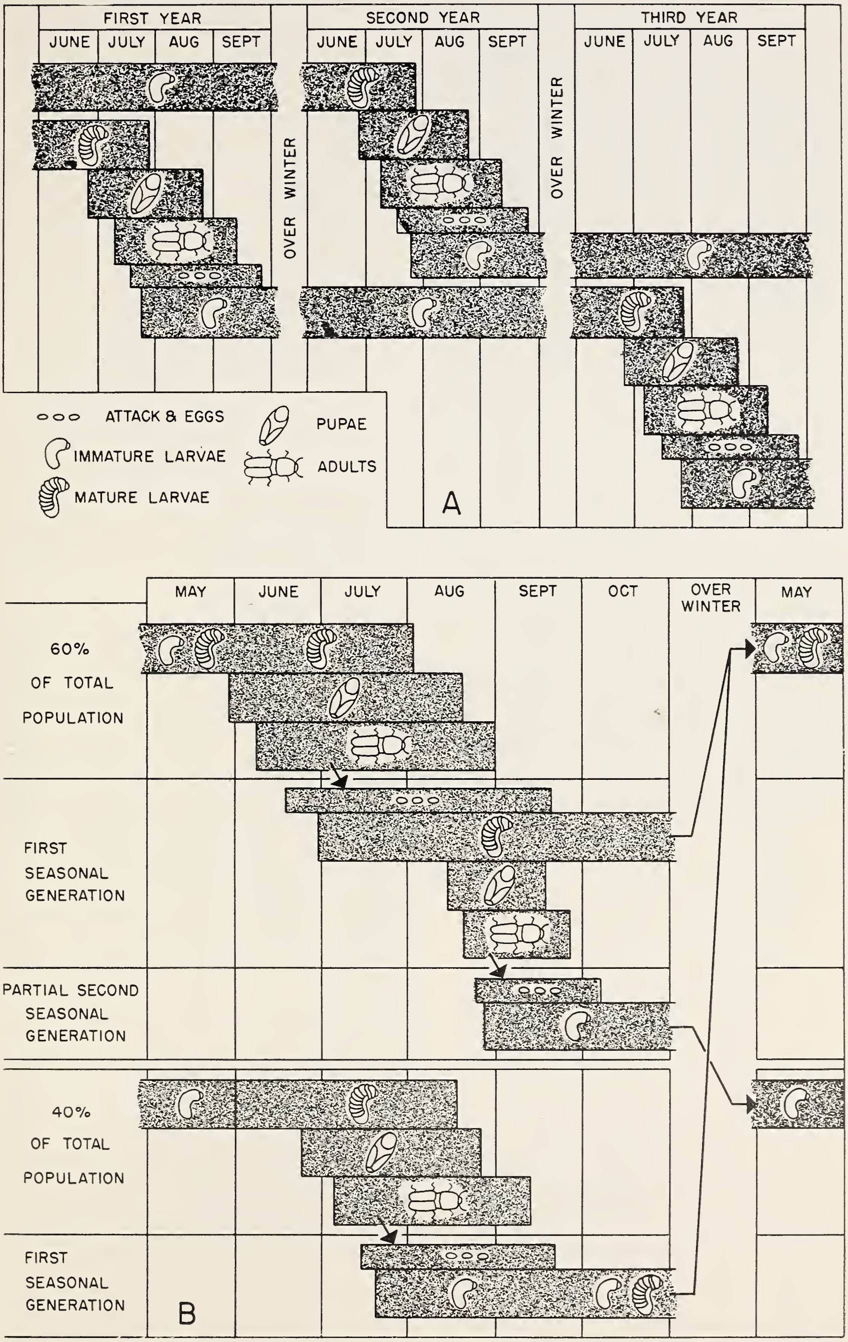

Figure 5.—Seasonal history of fir engraver in the Sierra Nevada Mountains: *A*, Minimum rate of development at 6,000 to 8,000 feet elevation; *B*, maximum rate of development at 3,500 to 6,000 feet elevation.

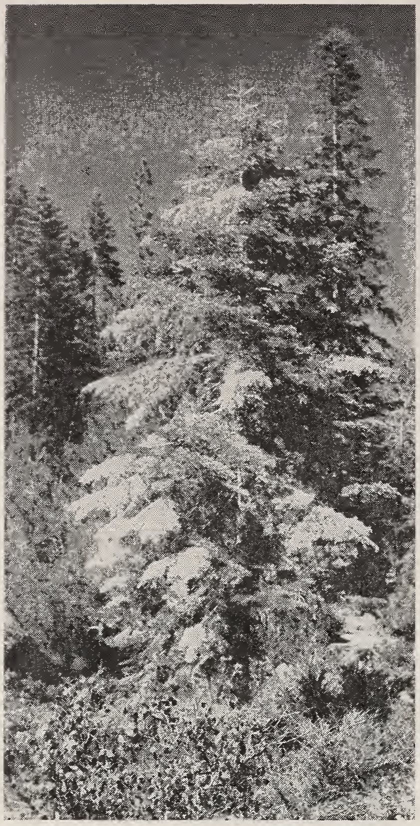

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Figure 6.—Fading branches among green ones, the result of partial trunk injury or patch killing by the fir engraver.

Top Killing

Top killing, while probably no more frequent than partial killing of the trunk, is far more conspicuous (fig. 9). Fading and reddish-brown tops, old spike tops, and secondary leaders forming new tops are common in fir forests. Extent of crown killed varies widely, but often reaches as high as 90 percent of the total length. Different ages of top killing frequently occur in the same tree over a period of several years. Some trees are killed by successive attacks by fir engravers; others are killed by secondary insects. Weakened mature trees are especially attractive to secondary bark- and wood-boring beetles.

Types of Injury

Injury or killing of trees by the fir engraver can be divided into three distinct recognizable types (table 1). Type 1 includes all top killing; type 2, trees injured in scattered areas along the bole; type 3, trees entirely killed. Type 3 is divided into three subtypes—A, B, and C—according to age of host, character of attack, and years required to kill. Although the fir engraver is primary in all types, the roundheaded fir borer (*Tetropium abietis* Fall) is an important factor in killing old and mature trees in types 3B and 3C.

HOST SUSCEPTIBILITY AND RESISTANCE

Field Observations

The causes underlying fir engraver outbreaks are not clear. Limited evidence resulting from observations since 1925 points toward lowered resistance of the trees as a main contributing factor.

In California and southern Oregon, some outbreaks were associated with a precipitation deficiency for 2 or more years preceding the outbreak. Outbreaks from 1928 to 1932, and again from 1949 to 1952, occurred after an extended period of subnormal precipitation. Outbreaks between these two periods, however, showed no apparent association with lowered precipitation.

In the interior Western States, epidemics have been reported several times since 1935, but in only two did the records indicate a cause. The outbreaks in Bryce Canyon,

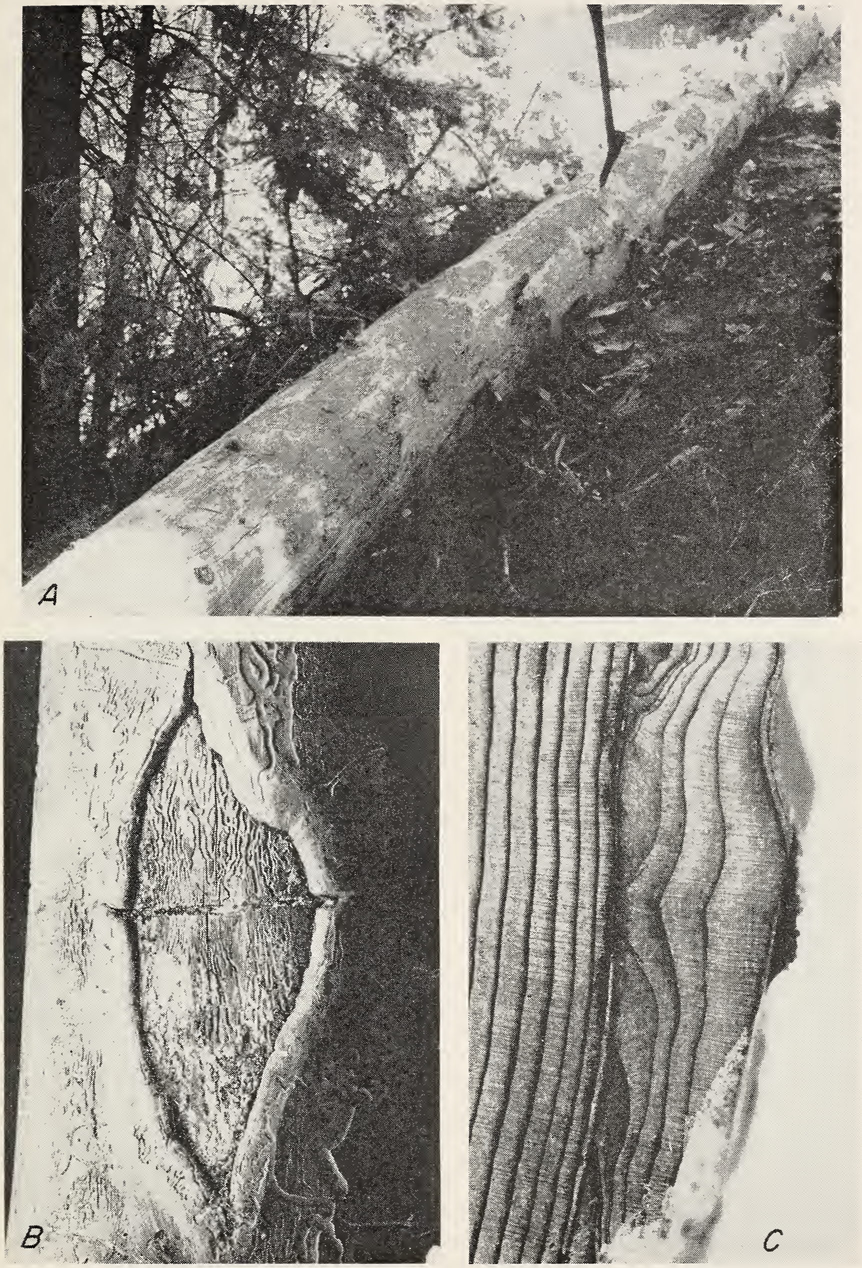

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Figure 7.—Patch killing by the fir engraver: *A*, Log of white fir with bark removed to show dead areas of cambium along main bole where broods developed; *B*, old attack partly buried by healing tissue before tree was killed several years later; *C*, old attack buried completely, shown in cross section as a darkened annual ring.

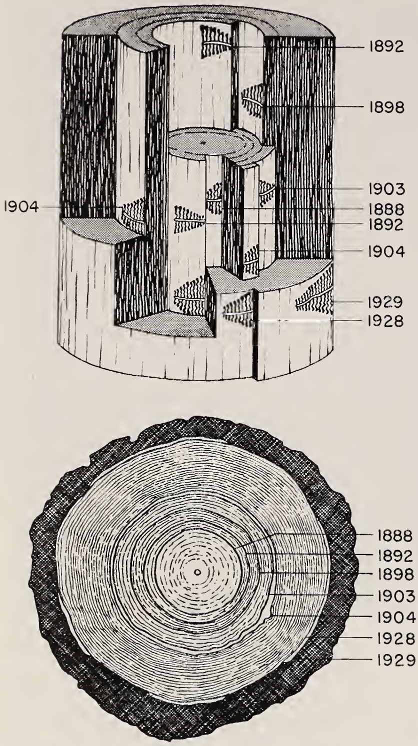

Figure 8.—Scars of periodic attacks by fir engraver are often healed over and buried in the wood. *Above,* Diagrammatic sketch of fir trunk with different wood layers bared to reveal old beetle attacks. *Below,* Cross section of trunk revealing the scars as deeply stained annual rings. (Dates of each attack are indicated. Adapted from an actual section of a fir tree.)

Utah, in 1952 and 1953 occurred after severe needle miner (*Epinotia meritana* Hein.) infestations. The serious outbreak in the Sandia Mountains, Cibola National Forest, New Mex., from 1951 through 1955, was associated with extended drought and a spruce budworm (*Choristoneura fumiferana* (Clem.)) outbreak.

These observations indicate that the fir engraver becomes especially destructive in periods when general host vigor is lowered. Reasons are still to be found for killing or top killing of trees when moisture, growth rate, and site index are favorable for tree growth. To find the answers will require a much fuller understanding of the relation between the biotic tendencies of the beetle, its natural control factors, and the resistance or susceptibility of the host.

Resistance of Trees to Controlled Attacks

In a series of experiments under controlled conditions, adult beetles were forced to attack caged parts of the trunks on 11 trees selected

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Figure 9.—Top-killed white fir. Upper third of crown faded as a result of top girdling by fir engraver.

Table 1.—*Classification of fir injury and killing*

Type No.	Part of tree killed	Frequency	Insect responsible
1	Top only, or a combination of top and patch killing.	Common in all stands, but more frequent in mature virgin stands.	Fir engraver.
2	Patches killed on main trunk, often healing, but weakening vigor of tree.	In all fir stands, but more prevalent in virgin stands.	Do.
3A	Entire tree killed by attack in one season in young and second-growth stands.	Result of beetle epidemics in second-growth stands of pole-size trees and larger.	Do.
3B	Entire tree killed by attack in one season in old mature stands.	Frequent in mature virgin stands.	Fir engraver and round-headed fir borer.
3C	Entire tree killed by successive attacks occurring over a period of years, usually in mature stands.	Common in all white fir stands, especially in mature trees.	Do.

as varying in site and growth rate. The height of the cage on the tree, the area of bark surface covered by the cage, and the number of beetles forced to attack were also varied. This method of studying beetle-host relationship resulted in complete failure of attacks under all conditions tried.

The number of attacks attempted was far in excess of the number of beetles admitted to caged areas, but most of them penetrated no farther than the outer part of the inner bark. Repeated attacks by the same adults were repelled each time by conditions the beetle encountered when first entering the bark. Only a few burrows were extended into the beginnings of egg galleries and none of these was excavated beyond 2 inches. Eggs that were deposited in a few of the longest galleries failed to hatch.

Balsam as a Repellent

Although no reasons for the failure of attacks were shown by the caging experiments, a partial explanation is indicated by demonstrated toxic and repellent qualities of balsam to fir engraver adults. Tests showed that a thin film of balsam placed on active adults caused immobility within less than 10 seconds, and later death. A small amount of balsam placed a short distance in front of approaching adults caused hurried reversal of direction.

Balsam, produced in living fir bark, is found in blisters, channels, and different sized reservoirs along the middle and upper bole, and varies widely in amount and distribution in different trees. Variations in amount of balsam, possibly owing to physiological changes within the host tree, may be a primary factor permitting the successful establishment of the fir engraver.

ASSOCIATED INSECTS

Many species of insects are attracted to fir trees after they have been weakened by the fir engraver or other agents. Frequently certain species attack before the fir engraver, or may even kill a tree. All of these insects attack living

trees, but some are more successful than others in their ability to establish broods. None of the associated insects has been studied to the same extent as the fir engraver.

Scolytidae

Scolytus praeceps Lec., as a rule, attacks the tops under 4 inches in diameter and often the larger branches of trees, after the fir engraver has begun an attack. Sapling fir trees growing under favorable conditions are occasionally attacked and killed by *S. praeceps.* It resembles the fir engraver in general appearance and activity but is much smaller. It cuts short, transverse egg galleries through the cambium, grooving the sapwood and inner bark (fig. 10).

The larval habits and mines of *Scolytus praeceps* are similar to those of the fir engraver. Pupation, as a rule, occurs in cells lying immediately below the surface of the sapwood. One generation is produced each year. Adults are in flight from June through September. A fungus stain organism similar in character to that associated with the fir engraver has been described by Wright[4] as *Spicaria anomala* (Corda) Harz.

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Figure 10.—Egg gallery and larval mines of Scolytus praeceps grooving sapwood surface of the main stem in top of white fir.

Scolytus subscaber Lec. in general appearance is similar to the fir engraver, but is somewhat longer and more robust and has very different habits (fig. 11). For a long time it was confused with the fir engraver. *S. subscaber* prefers gnarly or mistletoe-infected branches in which to establish broods, but also frequently attacks the main trunk of suppressed trees under 4 inches in diameter. Eggs are packed closely in niches made in the inner bark along the outer rim of an egg gallery.

The egg gallery of *Scolytus subscaber* is much shorter than that of the fir engraver, seldom being more than 14 mm. long. It is an anchor-shaped pattern and grooves the sapwood. Larvae feed individually in mines radiating from the egg gallery. At first the inner bark only is mined out. Later, as the larvae approach maturity, they mine along the surface of the sapwood. Attacks are made during July and August. The same species of staining fungi associated with *S. praeceps* is found associated with this bark beetle.

The grand fir bark beetle (*Pseudohylesinus grandis* Sw.) is a grayish-brown beetle slightly smaller than the fir engraver. It works

[4] Wright, Ernest. further investigations of brown-staining fungi associated with engraver beetles (scolytus) in white fir. Jour. Agr. Res. 57: 759–773, illus. 1938.

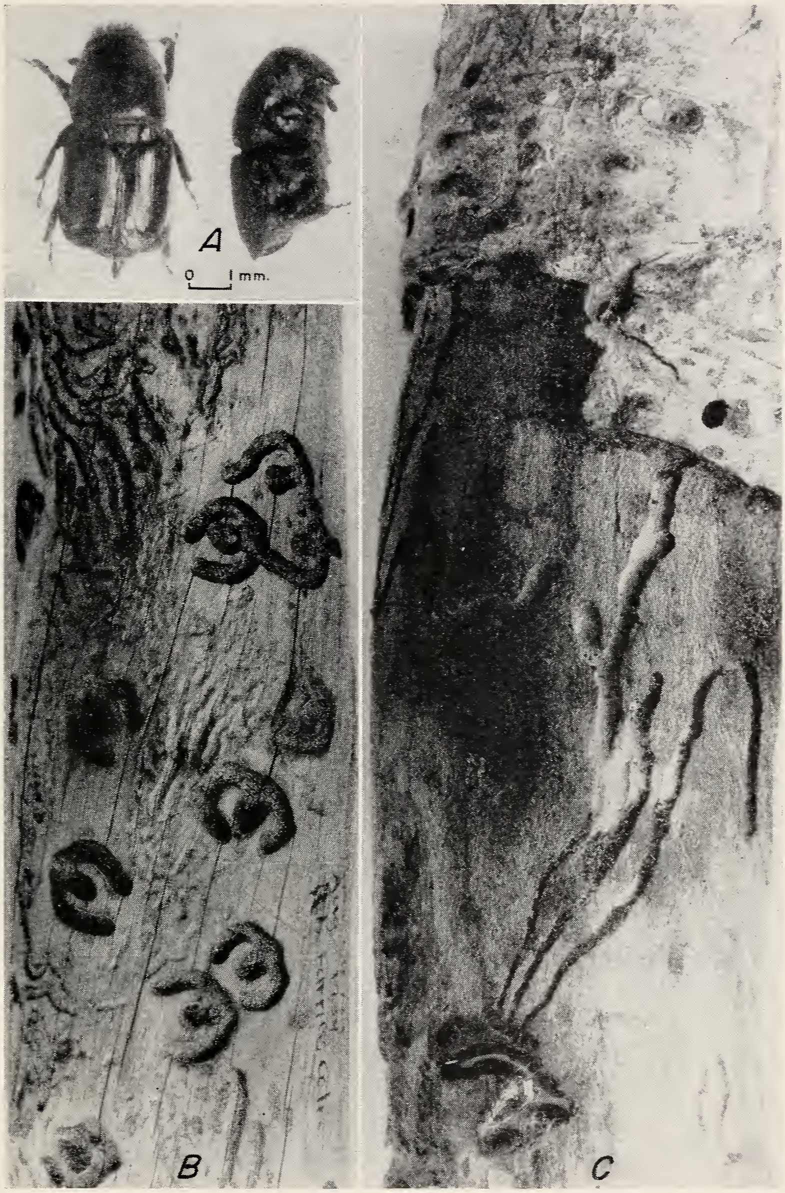

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Figure 11.—*Scolytus subscaber.* *A*, Dorsal and lateral aspects of adult. *B*, Section of weathered branch showing anchor-shaped egg galleries. C, Section of branch showing larval mines radiating from egg gallery in inner bark.

along the middle part of the main trunk of dying and dead fir trees and cut logs. Transverse egg galleries, 2 to 4 inches long, groove the sapwood and inner bark surfaces. One generation is completed each year.

Gnathotricus sulcatus (Lec.) is a small, dark reddish-brown, elongate ambrosia beetle, 3 to 3.5 mm. long. It is common near the base of dying and dead trees, seldom working higher than 10 feet from the ground. Its presence is revealed by fine borings in bark crevices, which are traceable to small round holes penetrating the sapwood to the interior of the trunk. A fungus cultivated near the ends of its galleries serves as food for developing broods.

Wilson's wide-headed ambrosia beetle (*Platypus wilsoni* Sw.) is a small, dark reddish-brown, elongate ambrosia beetle somewhat larger than *Gnathotricus sulcatus*. It is 5 to 5.5 mm. long. Each elytron terminates in a point. It works in the lower bole of dying and dead trees in much the same way as *G. sulcatus*, and may frequently extend its activity as high as 40 feet. Shredded white borings in bark crevices indicate its presence. It bores through the sapwood to the interior of the trunk, where it cultivates a fungus which serves as food for developing broods.

Pityophthorus pseudotsugae Sw. is a tiny, elongate, dark reddish-brown to black species. It works in the top of dying or weakened fir, mostly in large trees. It occasionally is a primary cause of death to firs of sapling size. Its tiny egg galleries radiate from a central nuptial chamber. The galleries and the nuptial chamber groove the sapwood and inner bark surfaces. This species is polygamous. One to two generations are produced each year, depending on seasonal temperatures.

Cerambycidae

The roundheaded fir borer (*Tetropium abietis* Fall) is of particular importance because of its ability to kill weakened fir trees without the assistance of the fir engraver beetle. It attacks and often overcomes mature trees that are suppressed in growth or otherwise weakened. Working also in the lower bole of trees severely injured in the top by the fir engraver, it hastens their death. Some trees recover from attacks of *Tetropium* and the scars are buried in the wood.

Although primary at times, the roundheaded fir borer has shown no tendency to become abnormally abundant or injurious. The larvae feed in the cambium, each cutting a winding mine packed with borings and frass. The mines increase in width with larval development. Pupation takes place near the outer bark. One generation is produced each year. Adults are found during June, July, and August.

The Oregon fir sawyer (*Monochamus oregonensis* Lec.) is a large, robust, black species, often with white markings, and is from 18 to 30 mm. long. It works in the top part of dying and dead fir trees less than 10 inches in diameter. The larvae groove the sapwood surface deeply, later entering the wood. Coarse shredded borings of wood are cast to the outside. One generation is produced each year.

Leptostylus nebulosus Horn is a mottled gray beetle, 12 to 18 mm. long, and robust. Its broods are produced in the tops of freshly killed fir. One generation is produced each year.

Buprestidae

The flatheaded fir borer (*Melanophila drummondi* (Kby.)) is a medium-sized, iridescent black or brown beetle with white spots on

the elytra. It is from 9 to 14 mm. long. It breeds most frequently in the middle part of the main trunk, but its attacks often extend for the entire length of the bole. Weakened or dying trees and cut logs exposed to full sunlight are most attractive to this insect. It constructs wide, flat, winding larval mines along the cambium layer. Pupation occurs in the outer bark. One generation is produced each year.

CONTROL

Natural Enemies

Parasitic and predacious insect enemies sometimes destroy as much as 84 percent of the brood of the fir engraver. Most of the enemies follow very closely after the establishment of a brood and develop at a similar rate, but others are not active until a brood is nearly mature. Some are voracious feeders, devouring many larvae and pupae before completing development; others remain with and complete development to maturity on a single host larva. Some are general predators and at times are cannibalistic.

The ostomatid beetle *Temnochila virescens* (Fab.) var. *chlorodia* (Mann.) is a general predator in both adult and larval stages and is associated with many species of bark beetles. The adult is iridescent blue or green, 10 to 15 mm. long, and elongate. The eggs are laid in bark crevices. Its seasonal development proceeds at about the same rate as that of the fir engraver.

The clerid beetle *Enoclerus lecontei* Wolc. is predacious in the larval and adult stages. It, too, is found commonly with bark beetles, especially with western pine beetle. The adults are 6 to 8 mm. long, black with grayish markings, and very active, resembling ants. The eggs are laid under bark scales or in crevices. The larvae feed on bark-beetle broods.

The clerid beetle *Enoclerus sphegeus* Fab. is frequently found with the fir engraver, but is more common with mountain pine beetle and certain other bark beetles. It is predacious in both larval and adult stages. The adult is 10 to 12 mm. long, black with gray markings, and with the ventral part of the abdomen reddish orange.

The clerid beetle *Thanasimus undulatus* Say is found occasionally on trees infested by the fir engraver. It is similar in size and appearance to *Enoclerus lecontei*. The abdomen and legs are reddish orange. Adults and larvae are predacious on broods of fir engraver.

Medeterus sp. is a small, gray, long-legged, larvaevorid fly, somewhat smaller than the housefly. The larvae commonly feed on fir engraver larvae. This fly also is associated with many other bark beetles.

The braconid *Coeloides scolyti* Cush. is parasitic in the larval stage. The adult is a small wasp with the head and abdomen orange and the thorax black. This insect is abundant from May to September in the vicinity of trees infested by the fir engraver. It has a medium-length ovipositor and deposits its eggs on the engraver larvae by inserting the ovipositor through the bark. The larvae are ectoparasites.

The adult of *Coeloides brunneri* Vier. is very similar in appearance to *C. scolyti* and is somewhat larger. It is quite similar in habits to *C. scolyti* but is not so prevalent.

Cecidostiba thomsoni Cwfd. is a small, greenish braconid wasp with a pointed abdomen and short ovipositor. It is found commonly, but is not as abundant as either of the other two parasites. The larvae is an ectoparasite.

The acarid *Pediculoides ventrocosus* Newport is a tiny, round, yellowish-white mite, and is an ectoparasite on fir engraver eggs, larvae, pupae, and adults (fig. 12). It is also found commonly with other bark beetles.

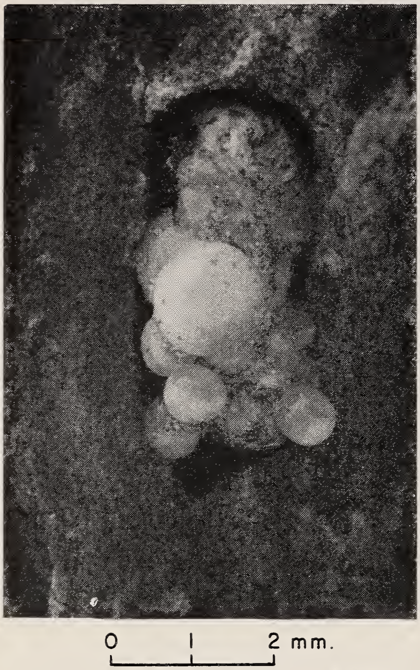

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Figure 12.—Predation on fir engraver larvae in pupal cell by mites, *Pediculoides ventricosus*.

Direct Methods

To control the fir engraver, a high percentage of the beetle population must be found and wiped out. This is not an easy goal to reach. Partially infested trees are hard to spot because only a few branches fade. Furthermore, the trees soon recover from the attacks. Fading foliage is easier to see in top-killed trees, but a good many of these trees are likely to recover, too. Yet top-killed and patch-killed trees may make up at least half the infested trees. The rest are killed outright, but whether they harbor the highest populations of beetles has never been determined. Controlling the beetles in dead trees and ignoring those in the others is not sound practice; therefore, direct control is generally not practicable.

Direct control may be practicable, however, in situations where extra effort is justified to protect valuable trees. Here it will pay to seek out all types of infestations, fell the trees, and destroy the fir engraver broods.

Several methods will work. Tests made in the 1930's on felled trees produced these results:

1. Peeling the infested bark off the top half of the log and scorching the rest, as in ordinary methods used in western pine beetle control, resulted in 100 percent mortality of the engraver.
2. Sun-curing killed beetles in bark up to ¾-inch thick when air temperatures were 80° F. or over. Logs were exposed to full sunlight for at least 6 hours daily while lying in a north and south direction, and turned one-third over every 5 days until all surfaces have been exposed.
3. Submerging brood logs in water for 6 weeks resulted in 99 percent mortality. Control by submergence is feasible near lake shores or mill ponds only when brood logs can be left in the water for a considerable period.
4. Application of dusts and oils was ineffective. Those tested were sodium fluosilicate dust, creosote emulsion, petroleum oils, and paradichlorobenzene dissolved in linseed oil.

In more recent tests success was obtained with two new insecticides. Field and laboratory experiments were conducted in 1952 against epidemic fir engraver attacks in the

Sandia Mountain recreational area, New Mexico.[5] Ethylene dibromide and orthodichlorobenzene diluted with fuel oil both killed more than 95 percent of the insects. The chemicals were applied as a fan-shaped stream to bolts from infested logs and to standing infested trees. The most effective dosages were 2 pounds of ethylene dibromide in 5 gallons of fuel oil and 8 pounds of orthodichlorobenzene in 5 gallons of fuel oil.

Caution: Any ethylene dibromide spray spilled on the skin should be washed off immediately with soap and water. Inhalation of the fumes of the spray should be avoided. Care should also be used in handling orthodichlorobenzene spray; it is extremely irritating to the eyes.

Indirect Methods

Indirect methods may lessen the hazard of fir engraver damage. These methods include harvest of suppressed, insect-infested, and diseased trees, and thinning where necessary to reduce competition among vigorous trees. Also, the control of persistent, stand-weakening infestations of defoilating insects, like the spruce budworm, should help to reduce the beetle hazard. These precautionary steps should reduce the amount of favored host material. By so doing, they should also reduce the chances of outbreaks. However, the extent to which this is true has never been demonstrated experimentally.

Summary

The fir engraver is a major cause of damage and death to forests of fir in the West. Sporadic outbreaks in both old- and second-growth stands have occurred one or more times each decade since 1925 in California and Oregon; elsewhere, since 1935, several epidemics have severely depleted fir stands.

White fir, lowland white fir, and California red fir are the preferred host trees, but the engraver occasionally damages Douglas-fir, mountain hemlock, alpine fir, and Engelmann spruce. The range of the fir engraver is known to extend from British Columbia to New Mexico and east to the Rocky Mountains.

The beetle kills or damages its host by cutting transverse egg galleries along the cambium layer, girdling the trunk or killing patches of cambium. The larvae mine separate channels at right angles to the egg gallery along the cambium layer, causing further damage. A fungus stain introduced by the beetle and found with every attack is apparently an important factor in ensuring the success of the beetle by helping to overcome the resistance of the host.

The length of the life cycle depends on prevailing temperatures at the altitude and latitude of the host trees. In the central Sierra Nevada one generation is produced each year at elevations between 4,500 and 6,000 feet; one generation every 2 years at elevations above 6,000 feet on north exposures; and one and a partial second generation each year at elevations between 3,500 and 4,500 feet on south exposures. All broods remain as dormant larvae during the winter months.

When beetle populations are low, and also presumably when tree growth and resistance are high, the fir engraver tends to continue its attacks to old or weakened trees, killing the tops or patches of cam-

[5] Nagel, R. H. Chemical control of the fir engraver. Manuscript on file at U. S. Forest Service Rocky Mountain Forest and Range Expt. Sta. 5 pp. 1956.

bium along the bole. Often it attacks and kills new leaders that have grown out to replace the old tops. Top killing often continues on the same trees for several years, each season of attack resulting in additional crown injury, until the tree is weakened beyond recovery. In vigorous trees, injured patches of cambium ordinarily heal over and the scars are buried in the wood.

During outbreaks entire trees and groups of trees are killed in a single season. At such times trees of all ages above 4 inches diameter at breast height may be attacked without apparent choice as to site or growth rate.

Trees weakened by the fir engraver are often readily attacked and killed by several species of associated secondary insects. The roundheaded fir borer (*Tetropium abietis*) is the most important in this group.

The fir engraver is held in check naturally by several species of parasitic and predacious insect enemies whose numbers increase with the numerical increase of the beetle.

Artificial control measures are limited because of the wide variation in injury to the host and in brood establishment. Unless the broods in top-killed trees or in partially injured boles can be destroyed, the benefit from destroying broods in dead trees is largely nullified. Insecticides which offer promise in controlling the fir engraver are toxic oil sprays containing either ethylene dibromide (2 pounds to 5 gallons of fuel oil), or orthodichlorobenzene (8 pounds to 5 gallons of fuel oil).

The best possibilities for minimizing fir engraver damage may lie in the removal of decadent and weakened firs and in improving the growth and vigor of the remaining stand.

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